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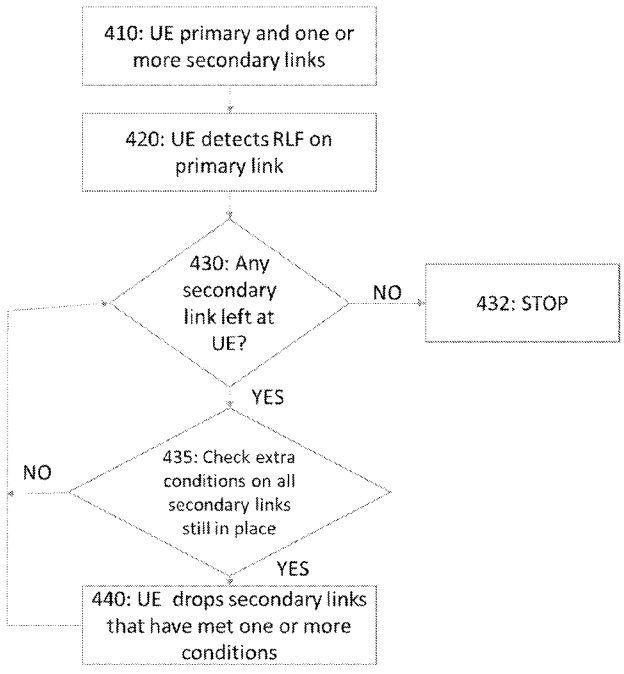

FIGURE 4

(57) Abstract: In accordance with the example embodiments of the invention there is at least a method and apparatus to perform establishing a connection to a network node of a communication network, wherein the connection comprises a primary link connection to a first network node and one or more secondary link connections to nodes of a same or different network; detecting a radio link failure on the primary link connection (420); and based on determining that one or more further conditions are not present (435), maintaining at least one of the one or more secondary link connections. Further, there is performing communicating over a connection with a user equipment, wherein the connection comprises a primary link connection to the user equipment and one or more secondary link connections to nodes of a same or different network; detecting a radio link failure on the primary link connection; and based on determining that one or more further conditions are not present, maintaining at least one of the one or more secondary link connections.

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MAINTAINING SECOND LINK IN AGGREGATION OPERATIONS DURING PRIMARY LINK RLF

TECHNICAL FIELD:

[0001] The teachings in accordance with the exemplary embodiments of this invention relate generally to an enhancement mechanism for dual and multi-link connectivity and, more specifically, relate to a modification of behavior of a network device upon detection of a radio link failure in order to maintain connectivity.

BACKGROUND:

[0002] This section is intended to provide a background or context to the invention that is recited in the claims. The description herein may include concepts that could be pursued, but are not necessarily ones that have been previously conceived or pursued. Therefore, unless otherwise indicated herein, what is described in this section is not prior art to the description and claims in this application and is not admitted to be prior art by inclusion in this section.

[0003] Certain abbreviations that may be found in the description and/or in the Figures are herewith defined as follows:

AS	Access Stratum
CN	Core Network
DRB	Data Radio Bearer
DC	dual connectivity
HO	Handover
LWA	LTE/WLAN Aggregation
MCG	Master Cell Group
MeNB	Master eNB
MRO	Mobility Robustness Optimization
NAS	Non Access Stratum
PCell	Primary Cell

PSCell	Primary Secondary Cell (the monitored cell of the SCG)
RLC	Radio Link Control
RLF	Radio Link Failure
RRC	Radio Resource Control
SCell	Secondary Cell
SCG	Secondary Cell Group
SeNB	Secondary eNB
TTT	Time to Trigger
X2	Interface between eNBs
X2AP	Application Protocol standardized for the X2 interface

[0004] E-UTRAN supports dual or multi- link connectivity such as LTE-WLAN aggregation (LWA) operation whereby a UE in RRC_CONNECTED can be configured by an eNB to utilize radio resources of more than one communication system.

[0005] It is noted that a network device such as a UE configured to use dual or multi-link connectivity such as via another communication system e.g., LWA may experience a radio link failure (RLF) because of poor quality of a primary communication system e.g., LTE link for example. In current standards the network releases connectivity with the device after detecting the RLF and the device will also drop the connectivity to a secondary connectivity source such as a WLAN AP, even if the secondary connectivity is operational. The example embodiments of the invention work to address at least this issue and improve on at least these operations.

SUMMARY:

[0006] This section contains examples of possible implementations and is not meant to be limiting.

[0007] In an example aspect of the invention, there is an apparatus, such as a communication network user equipment or mobile device, comprising: at least one processor; and at least one memory including computer program code, where the at least one memory and the computer program code are configured, with the at least one processor, to cause the apparatus to at least: establish a connection to a network node of a communication network,

wherein the connection comprises a primary link connection to a first network node and one or more secondary link connections to nodes of a same or different network; detect a radio link failure on the primary link connection; and based on determining that one or more further conditions are not present, maintain at least one of the one or more secondary link connections.

[0008] In another example aspect of the invention, there is a method comprising: establishing, by a user equipment, a connection to a network node of a communication network, wherein the connection comprises a primary link connection to a first network node and one or more secondary link connections to nodes of a same or different network; detecting, by the user equipment, a radio link failure on the primary link connection; and based on determining that one or more further conditions are not present, maintaining at least one of the one or more secondary link connections.

[0009] A further example embodiment is a method comprising the method of the previous paragraph, wherein the one or more further conditions comprises one or more of: the user equipment received an Radio Resource Control message from a different node/cell of the first network, data is no longer being received over all of the one or more secondary link connections for a predefined period, a radio link failure of all of the one or more secondary link connections is detected by the user equipment, and the network node has terminated all of the one or more secondary link connections; wherein radio link failure detection is performed at different times for each of the primary link connection and the one or more secondary link connections; and wherein determining if one or more further conditions are present is performed on a repeating basis, and where there is, based on determining that the one or more further conditions are present on all the one or more secondary link connections, dropping one or more secondary link connections; and entering, by the user equipment, an idle state if no secondary link connections are left.

[0010] A non-transitory computer-readable medium storing program code, the program code executed by at least one processor to perform at least the method as described in the paragraphs above.

[0011] In another example aspect of the invention, there is an apparatus comprising means for establishing a connection to a network node of a communication network, wherein the connection comprises a primary link connection to a first network node and one or more

secondary link connections to nodes of a same or different network; means for detecting a radio link failure on the primary link connection; and means, based on determining that one or more further conditions are not present, for maintaining at least one of the one or more secondary link connections.

[0012] In accordance with the example embodiments as described in the paragraph above, at least the means for establishing, detecting, and maintaining and/or dropping comprises a network interface, and computer program code stored on a computer-readable medium and executed by at least one processor.

[0013] In an example aspect of the invention, there is an apparatus, such as a communication network base station or other network device, comprising at least one processor; and at least one memory including computer program code, where the at least one memory and the computer program code are configured, with the at least one processor, to cause the apparatus to at least: communicate over a connection with a user equipment, wherein the connection comprises a primary link connection to the user equipment and one or more secondary link connections to nodes of a same or different network; detect a radio link failure on the primary link connection; and based on determining that one or more further conditions are not present, maintain at least one of the one or more secondary link connections.

[0014] In another example aspect of the invention, there is a method comprising: communicating, by a network node of a communication network, over a connection with a user equipment, wherein the connection comprises a primary link connection to the user equipment and one or more secondary link connections to nodes of a same or different network; detecting, by the network node, a radio link failure on the primary link connection; and based on determining that one or more further conditions are not present, maintaining at least one of the one or more secondary link connections.

[0015] A further example embodiment is a method comprising the method of the previous paragraph, wherein the one or more further conditions comprises one or more of: flow control feedback to the network node indicates that packets are not delivered to the user equipment over all of the one or more secondary link connections or that a number of packets delivered to the user equipment over all of the one or more secondary link connections is below a threshold, the user equipment has successfully re-established or connected to a new cell, the

network node is required to exchange security key related information with the user equipment, the network node receives but is not able to deliver non-access stratum messages to the user equipment, and there is no uplink traffic received from the user equipment via the one or more secondary link connections for a predefined period; wherein detecting the radio link failure comprises detecting that expected control plane information or data is no longer being received over the primary link connection; wherein radio link failure detection is using flow control feedback based on an amount of data delivered to the user equipment over a predefined period of time for each of the primary link connection and the one or more secondary link connections, and wherein the detecting is based on the flow control feedback indicating that the amount of data delivered to the user equipment is below an expected amount of delivered data during the predefined period of time; and wherein there is, based on determining that the one or more further conditions are present, dropping the one or more secondary link connections.

[0016] A non-transitory computer-readable medium storing program code, the program code executed by at least one processor to perform at least the method as described in the paragraphs above.

[0017] In another example aspect of the invention, there is an apparatus comprising means for means for communicating over a connection with a user equipment, wherein the connection comprises a primary link connection to the user equipment and one or more secondary link connections to nodes of a same or different network; means for detecting a radio link failure on the primary link connection; and means, based on determining that one or more further conditions are not present, for maintaining at least one of the one or more secondary link connections.

[0018] In accordance with the example embodiments as described in the paragraph above, at least the means for communicating, detecting, determining, and maintaining or dropping comprises a network interface, and computer program code stored on a computer-readable medium and executed by at least one processor.

BRIEF DESCRIPTION OF THE DRAWINGS:

[0019] The foregoing and other aspects of embodiments of this invention are made more evident in the following Detailed Description, when read in conjunction with the attached Drawing Figures, wherein:

[0020] Figure 1 shows an example of overall architecture of an 3GPP system for multi-connectivity;

[0021] Figure 2 shows a diagram illustrating an example of a User Equipment (UE) in partially overlapping cells;

[0022] Figure 3a shows radio link failure phases and impact on the RRC states;

[0023] Figure 3b shows radio link failure detection on network side;

[0024] Figure 4 shows a flow chart of operations in accordance with and example embodiment of the invention;

[0025] Figure 5 shows a high level block diagram of various devices used in carrying out various aspects of the invention; and

[0026] Figure 6a and 6b each show a method in accordance with example embodiments of the invention which may be performed by an apparatus.

DETAILED DESCRIPTION:

[0027] In accordance with the example embodiments of this invention, a new enhanced mechanism is proposed for the dual and multi-link connectivity that, in case of RLF of the primary link (e.g., the primary link can no longer be used for communication between the UE and eNB, both control and data plane), allows the UE to keep using the secondary link in place for a longer time. The secondary link (e.g., WLAN) is only dropped, if one of several additional

events on the UE and/or the eNB side is triggered. If the secondary link provides good connectivity, the primary link RLF may even go unnoticed by the user.

[0028] The example embodiments of the invention pertains to wireless communication with focus on Multi-RAT carrier aggregation, like for instance LTE WLAN aggregation (LWA), 4G and/or 5G multi-connectivity. In light of currently ongoing standardization activities [TR 36.300], the example embodiments of the invention is realized to be at least beneficial for LWA, but is not necessarily limited to it. The example embodiments can also be used to a benefit in 5G or any other radio communication technology which can include as multi-RAT network.

[0029] Figure 1 shows an example of a multi-point communication system which can be configured to perform the operations in accordance with the example embodiments of the invention. As shown in Figure 1, there is a UE 10 connected with for communication with a primary link 130 to a 3GPP Radio Node 13 via a 3GPP air interface and connected with a secondary link 150 via a secondary interface (e.g., WLAN interface) to a 3GPP logical node 15 controlling the secondary link. In addition, the 3GPP Radio Node 13 is connected to the 3GPP logical node 15 via a 3GPP RAN interface (e.g., Xw interface) over a communication path 120. The 3GPP Radio Node is also connected to the 3GPP Core Network 12 via a 3GPP interface 110.

[0030] Referring also to Figure 2, a user equipment (UE 10) as shown in Figure 1 may be connected to more than one cell at a same time. As shown in Figure 2 the UE 10 can be connected to a first cell 12 having a base station 13 (such as an eNB for example) and a second cell 14 having a base station 15 (such as an eNB or WLAN Access Point for example). The two cells 12, 14 are, thus, at least partially overlapping. In one type of example embodiment, the first cell may operate on a licensed band and the second one may operate on a licensed or an unlicensed band. For simplicity, there are just two cells depicted in the scenario shown in Figure 2. In other alternate examples any number of cells operating on licensed and/or unlicensed band(s) may be provided to work together for suitable multi-connectivity and/or Carrier Aggregation (CA).

[0031] It is noted that a UE configured to use dual or multi- link connectivity such as via another communication network (e.g. LWA) may experience an RLF because of poor

quality of the LTE link. The problem being addressed results from the fact that in current standards the UE will also drop the connectivity to the WLAN AP when the eNB releases the connectivity with the UE after detecting the RLF. However, the quality through the WLAN link may be good enough to continue the transmission of user data through this link. Thus, all the user data packets, which could have been still conveyed to the UE, are also dropped with all consequences of packet re-transmission, packet forwarding and TCP slow start.

[0032] A similar RLF detection may run in parallel in the eNB and in the UE. Figure 3a shows at the UE the phased approach of first waiting to get resynchronized (detecting in-sync indications) with the source cell. This resynchronization is referred to as the "first phase" as shown in Figure 3a. Phase 1 ends with expiration of timer T_1 (T310) and radio link failure (RLF) declaration, which is the starting point for the "second phase" T_2 (timer T311) that is dedicated to search for any allowed cells and try to re-establish with one of these cells. These phases occur after normal operation and these phases in recovery operations are to lead to successful re-establishing the primary link connection or entering an idle state which are performed beginning with a radio problem detection. During normal operation and the first and second phases the UE remains in an RRC_CONNECTED state even during the radio link failure and, if re-establishment was not possible or failed, returns to an RRC_IDLE state thereafter. It is noted that operations in accordance with the example embodiments of the invention as described herein may be performed during or prior to this "first phase" and/or "second phase" based on the radio problem detection as shown in Figure 3a. In accordance with the embodiments any of the radio problem detection and/or operations implements in the "first phase" or the "second phase" may or may not occur during the RRC_CONNECTED state as shown in Figure 3a.

[0033] Figure 3b shows radio problem and RLF detection on network side. As shown in Figure 3b if no re-establishment is possible or the re-establishment attempt fails then the eNB performs an eNB initiated UE release procedure, and the UE goes to idle and idle mobility rules according to TS 36.304 will apply and the UE must use the connection setup procedure with the network to change into the connected mode which implies to again begin to setup authentication, authorization and security on AS and NAS layers. As shown in Figure 3b during normal operation and a radio problem detection there is a no recovery period after a radio link failure time period (T_RLF). Then as shown in Figure 3b after this time period at point 320 the eNB initiated the UE release procedure. In accordance with the embodiments any of the radio

problem detection and/or operations implemented thereafter may trigger the operations in accordance with the example embodiments of the invention as described herein.

[0034] The example embodiments of the invention provide a modification of the behaviour of the UE and the eNB upon RLF detection as disclosed herein, in order to maintain the WLAN link for as long as needed. As mentioned, the embodiments of the invention are exemplarily described for the link aggregation with WLAN. It is noted that in accordance with the example embodiment the RLF detection operations may be performed multiple times and/or over a period of time.

[0035] Further, it is noted that in accordance with the example embodiments, multi-connectivity can consist of either a primary and multiple secondary connections or equally prioritized links in which case primary refers to the one from which the UE obeys control channel information.

[0036] Before describing the example embodiments of the invention in details, reference is made to Figure 5 for illustrating a simplified block diagram of various electronic devices that are suitable for use in practicing the example embodiments of this invention. In Figure 5 a wireless access network 9 is adapted for communication between a user equipment UE 10 and a network node NN 12 or other access node of an access network. In accordance with the example embodiments the NN 12 can be any network device e.g., a base station that is part of or separate from the network 9. The network 9 may include or may use a higher controlling node (not shown, by non-limiting example a gateway GW, a user plane entity UPE, a mobility management entity MME, or a system architecture evolution gateway SAE-GW) for operations in accordance with the example embodiments. Such a higher controlling node may be accessible via any communication link, including the antenna 10E and/or 12E, and/or via Internet 14.

[0037] The UE 10 includes a data processor (DP) 10A, a memory (MEM) 10B that stores a program (PROG) 10C, and a suitable radio frequency (RF) transmitter and receiver 10D coupled to one or more antennas 10E for bidirectional wireless communications over a data link 11 with the NN 12. The NN 12 also includes a DP 12A, a MEM 12B that stores a PROG 12C, and a suitable RF transmitter and receiver 12D coupled to one or more antennas 12E. The NN 12 may be coupled via a data link 13 to the internet or other broader

communication network. Further, though not shown in Figure 5, the UE 10 may also be coupled to the Internet 14, such as for secondary link connections as similarly disclosed herein. Also at the UE 10 and the NN 12 there are resource processors 10F, 12F, respectively, to include instructions for processing resource connection information for optimizing traffic flow discontinuities in accordance with the example embodiments of the invention as described herein. It is noted that the proposed use of the resource processors 10F and/or 12F is non-limiting and the operations in accordance with the example embodiments of the invention as described herein may be performed using other processing devices such as DP 10A and/or DP 12A as in Figure 5. At least one of the PROGs 10C and 12C is assumed to include program instructions that, when executed by the associated DP, enable the electronic device to operate in accordance with the example embodiments of this invention as described in detail below.

[0038] In general, the example embodiments of this invention may be implemented by computer software executable by the DP 10A of the UE 10 and by the DP12A of the NN 12, or other DPs, or by hardware, or by a combination of software and/or firmware and hardware. The interactions between the major logical elements should be obvious to those skilled in the art for the level of detail needed to gain an understanding of the broader aspects of the invention beyond only the specific examples herein. It should be noted that the invention may be implemented with an application specific integrated circuit ASIC, a field programmable gated array (FPGA), a digital signal processor or other suitable processor to carry out the intended function of the invention, including a central processor, a random access memory RAM, read only memory ROM, and communication ports for communicating between the NN 12 and the UE 10 as detailed above.

[0039] Further, it is noted that the various embodiments of the UE 10 can include, but are not limited to, cellular telephones, personal digital assistants (PDAs) having wireless communication capabilities, portable computers having wireless communication capabilities, image capture devices such as digital cameras having wireless communication capabilities, gaming devices having wireless communication capabilities, music storage and playback appliances having wireless communication capabilities, Internet appliances permitting wireless Internet access and browsing, as well as portable units or terminals that incorporate combinations of such functions.

[0040] The MEMs 10B and 12B may be of any type suitable to the local technical environment and may be implemented using any suitable data storage technology, such as semiconductor based memory devices, magnetic memory devices and systems, optical memory devices and systems, fixed memory and removable memory. The DPs 10A and 12A may be of any type suitable to the local technical environment, and may include one or more of general purpose computers, special purpose computers, microprocessors, digital signal processors (DSPs) and processors based on a multi-core processor architecture, as non-limiting examples.

[0041] At least one of the memories is assumed to tangibly embody software program instructions that, when executed by the associated processor, enable the electronic device to operate in accordance with the example embodiments of this invention, as detailed by example above. As such, the example embodiments of this invention may be implemented at least in part by computer software executable by the controller/DP of the UE 10 and/or the NN 12 by hardware, or by a combination of software and hardware.

[0042] Below is described example embodiments of the invention from the perspective of network devices such as the UE 10 and the NN 12 as in Figure 5.

[0043] **Embodiments on the UE side**: the UE, such as the UE 10 as in Figure 5, in LWA (or any dual- or multi-link connectivity status) will not release the secondary link via WLAN and also will not go to idle.

[0044] The UE will keep the LWA configuration, all the connection context and the WLAN link connections until one of the following events or conditions occurs:

- The UE receives a RRC Connection Reestablishment message i.e., a positive response or a RRC Connection Setup from a different cell;
- No data is any longer received on the WLAN link (plus TTT as data may arrive in a bursty or intermittent manner, e.g., this condition may be determined with a pre-defined timer whose values are known priori or received by the UE); and/or
- Implicitly due to eNB terminating LWA.

[0045] The advantage of keeping the context and configuration is that, if re-establishment to a different cell failed and the UE goes to Idle, the UE can try to re-connect to

the eNB where it experienced the RLF by performing a re-establishment procedure if the WLAN link is still running.

[0046] The UE can signal the capability of this new behaviour as a new IE in the UE capability so that the eNB can use the modified behaviour. If the UE has uplink traffic:

- The UE should pick the WLAN as primary link and send traffic to the eNB; and
- eNB can terminate the connection as described below, which will implicitly determine the UE to release the LWA as well (even without RRC signalling which is optional – see section 22A.1.7.3 in TS 36.300).

[0047] Figure 4 shows a flow chart of operations in accordance with and example embodiment of the invention. As shown in step 410 of Figure 4 there is a UE with a primary and one or more secondary links. As shown in step 420 the UE detects a radio link failure (RLF) on the primary link. At step 430 there is determining whether any secondary link remains active or is left at the UE. If the determination is that no secondary link is left active at the UE then as shown in step 432 the operations after RLF are performed as per existing standards. If the determination is that there is a secondary link(s) left active at the UE, then as shown in step 435 there is checking for each secondary link whether extra conditions are present one or more conditions are present or still in place. If for a secondary link it is determined that there are no further conditions present, then as shown in Figure 4 there is returning to step 430 to determine whether any other secondary link remains active or is left at the UE. If for a secondary link it is determined that there are further conditions present, then as shown in step 440 the UE drops the secondary links that have met the one or more further conditions.

[0048] **<u>Embodiments on the eNB side</u>**: A pre-requisite in accordance with the example embodiments of the invention can be that Xw based flow control is in place that can give a reliable feedback about the data transmitted to the UE via at least the WLAN link. The eNB, such as the NN 12 as in Figure 5, should continue sending data to the UE via the WLAN link and not release the UE context and LWA configuration for as long as possible or as needed. The eNB should stop the transmission, release LWA and the UE context once one of the stop conditions below is fulfilled. For example:

- Flow control feedback, such as over a pre-defined period of time, suggests that the WLAN link can no longer deliver packages to UE (for example, the amount of

required bits is very low or does not meet a threshold) during a predefined period of time. This can be considered as a RLF detection on a secondary link by the eNB/network node;

- The UE has successfully re-established or connected to another cell or a new cell e.g., an LTE cell (in the context of MRO, when the UE re-establishes after RLF the new eNB informs the old eNB via the RLF Indication message over X2 according to section 20.2.2.12 of TS 36.300. If MRO is not supported, the CN will inform the old eNB as soon as the new eNB triggers a path switch with the CN to receive the DL user data for this UE at the new eNB);
- The eNB is required to exchange security related information with the UE, e.g. the Access Stratum or Non-Access Stratum security keys;
- The eNB receives and is not able to deliver NAS messages to UE;
- No more UL traffic received from the UE via the WLAN link (plus TTT, in case UE just temporarily has no UL traffic to send); and
- Timer based (a pre-defined timer value can be scaled based on the UE's mobility class (if known), the size of the mobility set configured for the UE (if any).

[0049] The proposed method is an optimization in terms of minimization traffic flow discontinuities, i.e., not stopping the UE from recovering from a RLF, but let the traffic flow as long as is possible without primary link. Even if the UE does not manage to re-sync with the initial cell/ re-establish to a different one, the WLAN link may still be used for delivering data to/from the UE for some time.

[0050] Figure 6a illustrates operations which may be performed by a device such as, but not limited to, a device (e.g., the UE 10 as in Figure 5). As shown in step 610 of Figure 6a there is establishing, by a user equipment, a connection to a network node of a communication network, wherein the connection comprises a primary link connection to a first network node and one or more secondary link connections to nodes of a same or different network. As shown in step 620 of Figure 6a there is detecting, by the user equipment, a radio link failure on the primary link connection. Then as shown in step 630 of Figure 6a there is based on determining that one or more further conditions are not present, maintaining at least one of the one or more secondary link connections.

[0051] In accordance with the example embodiments as described in the paragraph above, the one or more further conditions comprises one or more of: the user equipment received an Radio Resource Control message from a different node/cell of the first network, data is no longer being received over all of the one or more secondary link connections for a predefined period, a radio link failure of all of the one or more secondary link connections is detected by the user equipment, and the network node has terminated all of the one or more secondary link connections.

[0052] In accordance with the example embodiments as described in the paragraphs above, radio link failure detection is performed at different times for each of the primary link connection and the one or more secondary link connections, and wherein determining if one or more further conditions are present is performed on a repeating basis.

[0053] In accordance with the example embodiments as described in the paragraphs above, there is, based on determining that the one or more further conditions are present on all the one or more secondary link connections, dropping one or more secondary link connections; and entering, by the user equipment, an idle state if no secondary link connections are left.

[0054] In accordance with the example embodiments as described in the paragraphs above, for a case it is determined that at least one of the secondary link connections is available, then there is dropping the unavailable secondary link connections and maintaining the at least one secondary link connections that is left.

[0055] In accordance with the example embodiments as described in the paragraphs above, the primary link connection is a long term evolution connection link and the at least one secondary link connection is a wireless local area network connection link.

[0056] A non-transitory computer-readable medium (MEM 10B of Figure 5) storing program code (PROG 10C of Figure 5), the program code executed by at least one processor (DP 10A and/or DP 10F of Figure 5) to perform the operations as at least described in the paragraphs above.

[0057] In accordance with an example embodiment of the invention as described above there is an apparatus comprising: means for establishing, by a user equipment (Antenna 10E, transmitter/receiver 10D of Figure 5), a connection to a network node of a communication network, wherein the connection comprises a primary link connection to a first network node [NN 12 of Figure 5 or eNB] and one or more secondary link connections to nodes of a same or different network of a communication network; means for detecting, by the user equipment [DP 10A and/or 10F, PROG 10C and MEM 10B of Figure 5], a radio link failure on the primary link connection; and means, based on determining [DP 10A and/or 10F, PROG 10C and MEM 10B of Figure 5] that one or more further conditions are not present, for maintaining at least one of the one or more secondary link connections if one or more further conditions are present.

[0058] In the example aspect of the invention according to the paragraph above, wherein at least the means for establishing, detecting, determining, and dropping or maintaining comprises a non-transitory computer readable medium [MEM 10B of Figure 5] encoded with a computer program [PROG 10C of Figure 5] executable by at least one processor [DP 10A and/or 10F of Figure 5].

[0059] Figure 6b illustrates operations which may be performed by a network device such as, but not limited to, a network node NN 12 as in Figure 5 or an eNB. As shown in step 650 of Figure 6b there is communicating, by a network node of a communication network, over a connection with a user equipment, wherein the connection comprises a primary link connection to the user equipment and one or more secondary link connections to nodes of a same or different network. As shown in step 660 there is detecting, by the network node, a radio link failure on the primary link connection. Then as shown in step 670 there is based on determining that one or more further conditions are not present, maintaining at least one of the one or more secondary link connections.

[0060] In accordance with the example embodiments as described in the paragraph above, the one or more further conditions comprises one or more of: flow control feedback to the network node indicates that packets are not delivered to the user equipment over all of the one or more secondary link connections or that a number of packets delivered to the user equipment over all of the one or more secondary link connections is below a threshold, the user equipment has successfully re-established or connected to a new cell, the network node is required to exchange security key related information with the user equipment, the network

node receives but is not able to deliver non-access stratum messages to the user equipment, and there is no uplink traffic received from the user equipment via the one or more secondary link connections for a predefined period.

[0061] In accordance with the example embodiments as described in the paragraphs above, detecting the radio link failure comprises detecting that expected control plane information is no longer being received over the primary link connection.

[0062] In accordance with the example embodiments as described in the paragraphs above, radio link failure detection is performed at different times for each of the primary link connection and the one or more secondary link connections, and wherein determining if one or more further conditions are present is performed on a repeating basis.

[0063] In accordance with the example embodiments as described in the paragraphs above, radio link failure detection by the apparatus is using flow control feedback based on an amount of data delivered to or received from the user equipment over said one or more secondary link connections, wherein the flow control feedback is indicating based on a threshold that an amount of data required to be delivered to or received from the user equipment during a predefined period of time is below a threshold

[0064] In accordance with the example embodiments as described in the paragraphs above, there is based on determining that the one or more further conditions are present on all the one or more secondary link connections, dropping the one or more secondary link connections.

[0065] In accordance with the example embodiments as described in the paragraphs above, for a case it is determined that at least one of the secondary link connections is available, then there is dropping the unavailable secondary link connections and maintaining the secondary link connections that are left.

[0066] A non-transitory computer-readable medium (MEM 10B of Figure 5) storing program code (PROG 12C of Figure 5), the program code executed by at least one processor (DP 12A and/or DP 12F of Figure 5) to perform the operations as at least described in the paragraphs above.

[0067] In accordance with an example embodiment of the invention as described above there is an apparatus comprising: means for communicating (Antenna 12E, transmitter/receiver 12D of Figure 5), by a network node of a communication network [NN 12 of Figure 5 or eNB], over a connection with a user equipment, wherein the connection comprises a primary link connection to the user equipment and one or more secondary link connections to nodes of a same or different network; means for detecting (DP 12A, DP 12F, PROG 12C, and/or MEM 12B of Figure 5), by the network node, a radio link failure on the primary link connection; means, based on determining that one or more further conditions are not present, for maintaining (Antenna 12E, transmitter/receiver 12D, DP 12A, DP 12F, PROG 12C, and/or MEM 12B of Figure 5) at least one of the one or more secondary link.

[0068] In the example aspect of the invention according to the paragraph above, wherein at least the means for establishing, detecting, determining, and dropping or maintaining comprises a non-transitory computer readable medium [MEM 12B] encoded with a computer program [PROG 12C] executable by at least one processor [DP 12A and/or 12F].

[0069] In general, the various embodiments may be implemented in hardware or special purpose circuits, software, logic or any combination thereof. For example, some aspects may be implemented in hardware, while other aspects may be implemented in firmware or software which may be executed by a controller, microprocessor or other computing device, although the invention is not limited thereto. While various aspects of the invention may be illustrated and described as block diagrams, flow charts, or using some other pictorial representation, it is well understood that these blocks, apparatus, systems, techniques or methods described herein may be implemented in, as non-limiting examples, hardware, software, firmware, special purpose circuits or logic, general purpose hardware or controller or other computing devices, or some combination thereof.

[0070] Embodiments of the inventions may be practiced in various components such as integrated circuit modules. The design of integrated circuits is by and large a highly automated process. Complex and powerful software tools are available for converting a logic level design into a semiconductor circuit design ready to be etched and formed on a semiconductor substrate.

[0071] The word "exemplary" as may be used herein is meant to mean "serving as an example, instance, or illustration." Any embodiment described herein as "exemplary" is not necessarily to be construed as preferred or advantageous over other embodiments. All of the embodiments described in this Detailed Description are exemplary embodiments provided to enable persons skilled in the art to make or use the invention and not to limit the scope of the invention which is defined by the claims.

[0072] The foregoing description has provided by way of exemplary and non-limiting examples a full and informative description of the best method and apparatus presently contemplated by the inventors for carrying out the invention. However, various modifications and adaptations may become apparent to those skilled in the relevant arts in view of the foregoing description, when read in conjunction with the accompanying drawings and the appended claims. However, all such and similar modifications of the teachings of this invention will still fall within the scope of this invention.

[0073] It should be noted that the terms "connected," "coupled," or any variant thereof, mean any connection or coupling, either direct or indirect, between two or more elements, and may encompass the presence of one or more intermediate elements between two elements that are "connected" or "coupled" together. The coupling or connection between the elements can be physical, logical, or a combination thereof. As employed herein two elements may be considered to be "connected" or "coupled" together by the use of one or more wires, cables and/or printed electrical connections, as well as by the use of electromagnetic energy, such as electromagnetic energy having wavelengths in the radio frequency region, the microwave region and the optical (both visible and invisible) region, as several non-limiting and non-exhaustive examples.

[0074] Furthermore, some of the features of the preferred embodiments of this invention could be used to advantage without the corresponding use of other features. As such, the foregoing description should be considered as merely illustrative of the principles of the invention, and not in limitation thereof.

CLAIMS

What is claimed is:

1. A method comprising:

establishing, by a user equipment, a connection to a network node of a communication network, wherein the connection comprises a primary link connection to a first network node and one or more secondary link connections to nodes of a same or different network;

detecting, by the user equipment, a radio link failure on the primary link connection; and

based on determining that one or more further conditions are not present, maintaining at least one of the one or more secondary link connections.

2. The method according to claim 1, wherein the one or more further conditions comprises one or more of:

the user equipment received an Radio Resource Control message from a different node/cell of the first network,

data is no longer being received over all of the one or more secondary link connections for a predefined period,

a radio link failure of all of the one or more secondary link connections is detected by the user equipment, and

the network node has terminated all of the one or more secondary link connections.

3. The method according to any one of claims 1 to 2, wherein radio link failure detection is performed at different times for each of the primary link connection and the one or more secondary link connections, and wherein determining if one or more further conditions are present is performed on a repeating basis.

4. The method according to claim 1, the method comprising:

based on determining that the one or more further conditions are present on all the one or more secondary link connections,

dropping the one or more secondary link connections; and

entering, by the user equipment, an idle state if no secondary link connections are left.

5. A non-transitory computer-readable medium storing program code, the program code executed by at least one processor to perform the method of any one of claims 1 to 4.

6. An apparatus comprising:

at least one processor; and

at least one memory including computer program code, where the at least one memory and the computer program code are configured, with the at least one processor, to cause the apparatus to at least:

establish a connection to a network node of a communication network, wherein the connection comprises a primary link connection to a first network node and one or more secondary link connections to nodes of a same or different network;

detect a radio link failure on the primary link connection; and

based on determining that one or more further conditions are not present, maintain at least one of the one or more secondary link connections.

7. The apparatus according to claim 6, wherein the one or more further conditions comprises one or more of:

the apparatus received an Radio Resource Control message from a different node/cell of the first network,

data is no longer being received over all of the one or more secondary link connections for a predefined period,

a radio link failure of all of the one or more secondary link connections is detected, and

the network node has terminated all of the one or more secondary link connections.

8. The apparatus according to any one of claims 6 to 7, wherein radio link failure detection is performed at different times for each of the primary link connection and the one or more secondary link connections, and wherein determining if one or more further conditions are present is performed on a repeating basis.

9. The apparatus according to claim 6, wherein the at least one memory including the computer program code is configured with the at least one processor to cause the apparatus to:

based on determining that the one or more further conditions are present on all the one or more secondary link connections,

drop one or more secondary link connections; and

enter an idle state if no secondary link connections are left.

10. An apparatus comprising:

means for establishing a connection to a network node of a communication network, wherein the connection comprises a primary link connection to a first network node and one or more secondary link connections to nodes of a same or different network;

means for detecting a radio link failure on the primary link connection; and

means, based on determining that one or more further conditions are not present, for maintaining at least one of the one or more secondary link connections.

11. The apparatus according to claim 10, wherein the one or more further conditions comprises one or more of:

the apparatus received an Radio Resource Control message from a different node/cell of the first network,

data is no longer being received over all of the one or more secondary link connections for a predefined period,

a radio link failure of all of the one or more secondary link connections is detected, and

the network node has terminated all of the one or more secondary link connections.

12. The apparatus according to any one of claims 10 to 11, wherein radio link failure detection is performed at different times for each of the primary link connection and the one or more secondary link connections, and wherein determining if one or more further conditions are present is performed on a repeating basis.

13. The apparatus according to claim 10, comprising:

means, based on determining that the one or more further conditions are present on all the one or more secondary link connections, for:

dropping one or more secondary link connections; and

entering an idle state if no secondary link connections are left.

14. A method comprising:

communicating, by a network node of a communication network, over a connection with a user equipment, wherein the connection comprises a primary link connection to the user equipment and one or more secondary link connections to nodes of a same or different network;

detecting, by the network node, a radio link failure on the primary link connection; and

based on determining that one or more further conditions are not present, maintaining at least one of the one or more secondary link connections.

15. The method according to claim 14, wherein detecting the radio link failure comprises detecting that expected control plane information or data is no longer being received over the primary link connection.

16. The method according to according to any one of claims 14 to 15, wherein the one or more further conditions comprises one or more of:

flow control feedback to the network node indicates that packets are not delivered to the user equipment over all of the one or more secondary link connections or that a number of packets delivered to the user equipment over all of the one or more secondary link connections is below a threshold,

the user equipment has successfully re-established or connected to a new cell,

the network node is required to exchange security key related information with the user equipment,

the network node receives but is not able to deliver non-access stratum messages to the user equipment, and

there is no uplink traffic received from the user equipment via the one or more secondary link connections for a predefined period.

17. The method according to claim 14, wherein radio link failure detection by the network node is using flow control feedback based on an amount of data delivered to or received from the user equipment over said one or more secondary link connections, wherein the flow control feedback is indicating based on a threshold that an amount of data required to be delivered to or received from the user equipment during a predefined period of time is below a threshold.

18. The method according to claim 14, the method comprising:

based on determining that the one or more further conditions are present on all the one or more secondary link connections, dropping the one or more secondary link connections.

19. A non-transitory computer-readable medium storing program code, the program code executed by at least one processor to perform the method of any one of claims 14 to 18.

20. An apparatus comprising:

at least one processor; and

at least one memory including computer program code, where the at least one memory and the computer program code are configured, with the at least one processor, to cause the apparatus to at least:

communicate over a connection with a user equipment, wherein the connection comprises a primary link connection to the user equipment and one or more secondary link connections to nodes of a same or different network;

detect a radio link failure on the primary link connection; and

based on determining that one or more further conditions are not present, maintain at least one of the one or more secondary link connections.

21. The apparatus according to claim 20, wherein detecting the radio link failure comprises detecting that expected control plane information is no longer being received over the primary link connection.

22. The apparatus according to claim 20, wherein the one or more further conditions comprises one or more of:

flow control feedback to the apparatus indicates that packets are not delivered to the user equipment over all of the one or more secondary link connections or that a number of packets delivered to the user equipment over all of the one or more secondary link connections is below a threshold,

the user equipment has successfully re-established or connected to a new cell,

the apparatus is required to exchange security key related information with the user equipment,

the apparatus receives but is not able to deliver non-access stratum messages to the user equipment, and

there is no uplink traffic received from the user equipment via the one or more secondary link connections for a predefined period.

23. The apparatus according to claim 20, wherein radio link failure detection by the apparatus is using flow control feedback based on an amount of data delivered to or received from the user equipment over said one or more secondary link connections, wherein the flow control feedback is indicating based on a threshold that an amount of data required to be delivered to or received from the user equipment during a predefined period of time is below a threshold.

24. The apparatus according to claim 20, wherein the at least one memory including the computer program code is configured with the at least one processor to cause the apparatus to:

based on determining that the one or more further conditions are present on all the one or more secondary link connections, drop the one or more secondary link connections.

25. An apparatus comprising:

means for communicating over a connection with a user equipment, wherein the connection comprises a primary link connection to the user equipment and one or more secondary link connections to nodes of a same or different network;

means for detecting a radio link failure on the primary link connection; and

means, based on determining that one or more further conditions are not present, for maintaining at least one of the one or more secondary link connections.

26. The apparatus according to claim 25, wherein detecting the radio link failure comprises detecting that expected control plane information is no longer being received over the primary link connection.

27. The apparatus according to claim 25, wherein the one or more further conditions comprises one or more of:

flow control feedback to the apparatus indicates that packets are not delivered to the user equipment over all of the one or more secondary link connections or that a number of packets delivered to the user equipment over all of the one or more secondary link connections is below a threshold,

the user equipment has successfully re-established or connected to a new cell,

the apparatus is required to exchange security key related information with the user equipment,

the apparatus receives but is not able to deliver non-access stratum messages to the user equipment, and

there is no uplink traffic received from the user equipment via the one or more secondary link connections for a predefined period.

28. The apparatus according to claim 25, wherein radio link failure detection by the apparatus is using flow control feedback based on an amount of data delivered to or received from the user equipment over said one or more secondary link connections, wherein the flow control feedback is indicating based on a threshold that an amount of data required to be delivered to or received from the user equipment during a predefined period of time is below a threshold.

29. The apparatus according to claim 25, comprising: means, based on determining that the one or more further conditions are present on all the one or more secondary link connections, for dropping the one or more secondary link connections.

30. A communication system comprising the apparatus in accordance with any one of the claims 6 to 9 and the apparatus in accordance with any one of the claims 20 to 24.

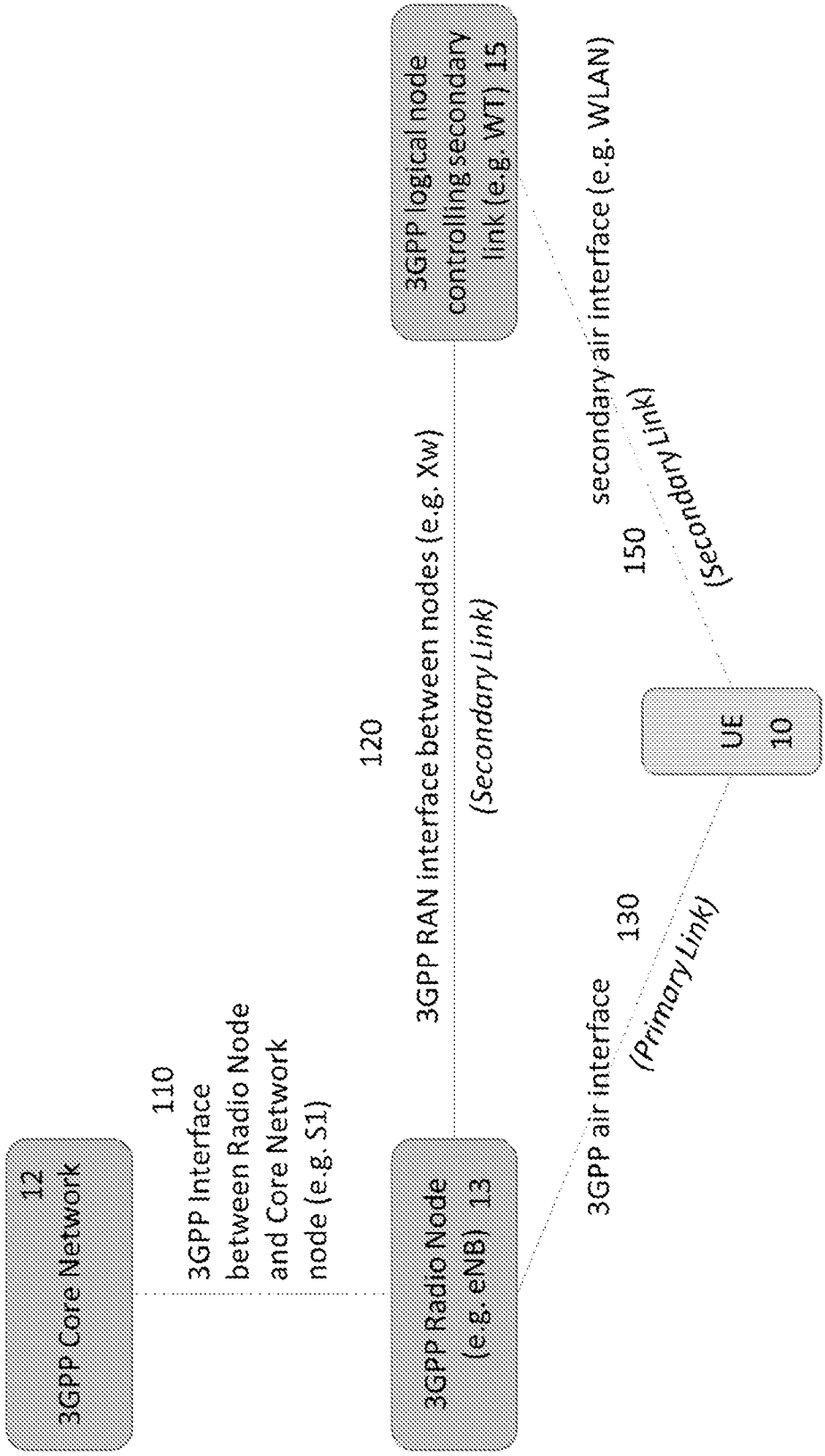
12
3GPP Core Network
110
3GPP Interface between Radio Node and Core Network node (e.g. S1)
3GPP Radio Node (e.g. eNB) 13
120
3GPP RAN interface between nodes (e.g. Xw)
(Secondary Link)
3GPP logical node controlling secondary link (e.g. WT) 15
130
3GPP air interface
(Primary Link)
150
secondary air interface (e.g. WLAN)
(Secondary Link)
UE
10

FIGURE 1

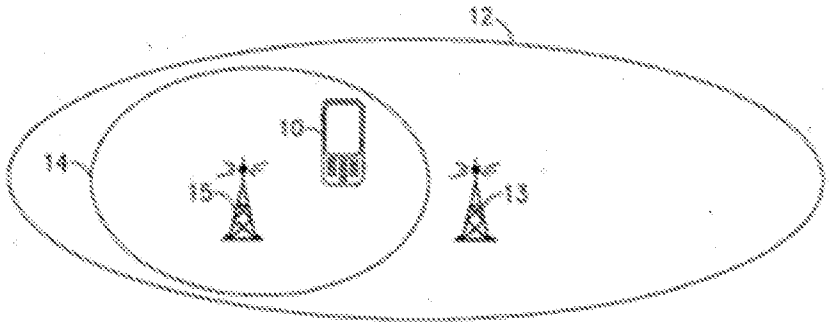

Figure 2

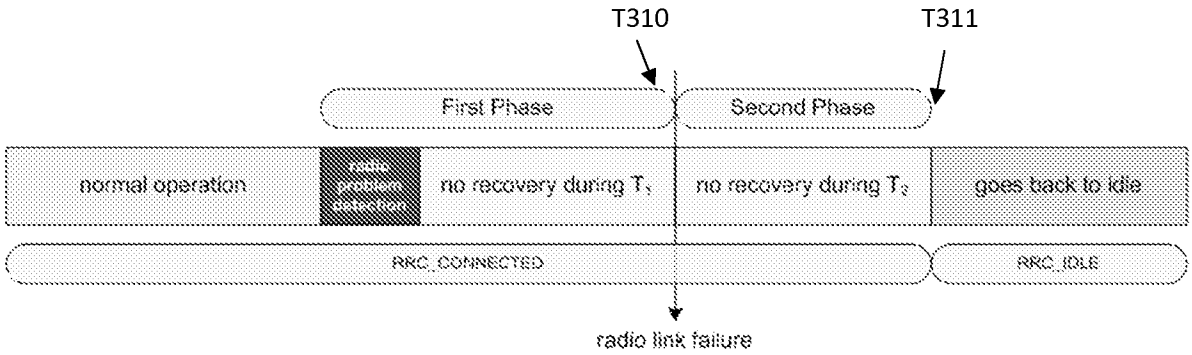

FIGURE 3a

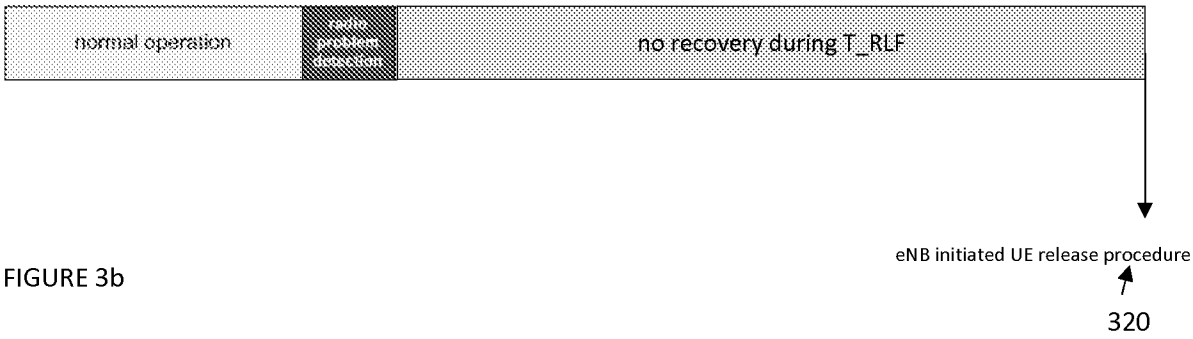

FIGURE 3b

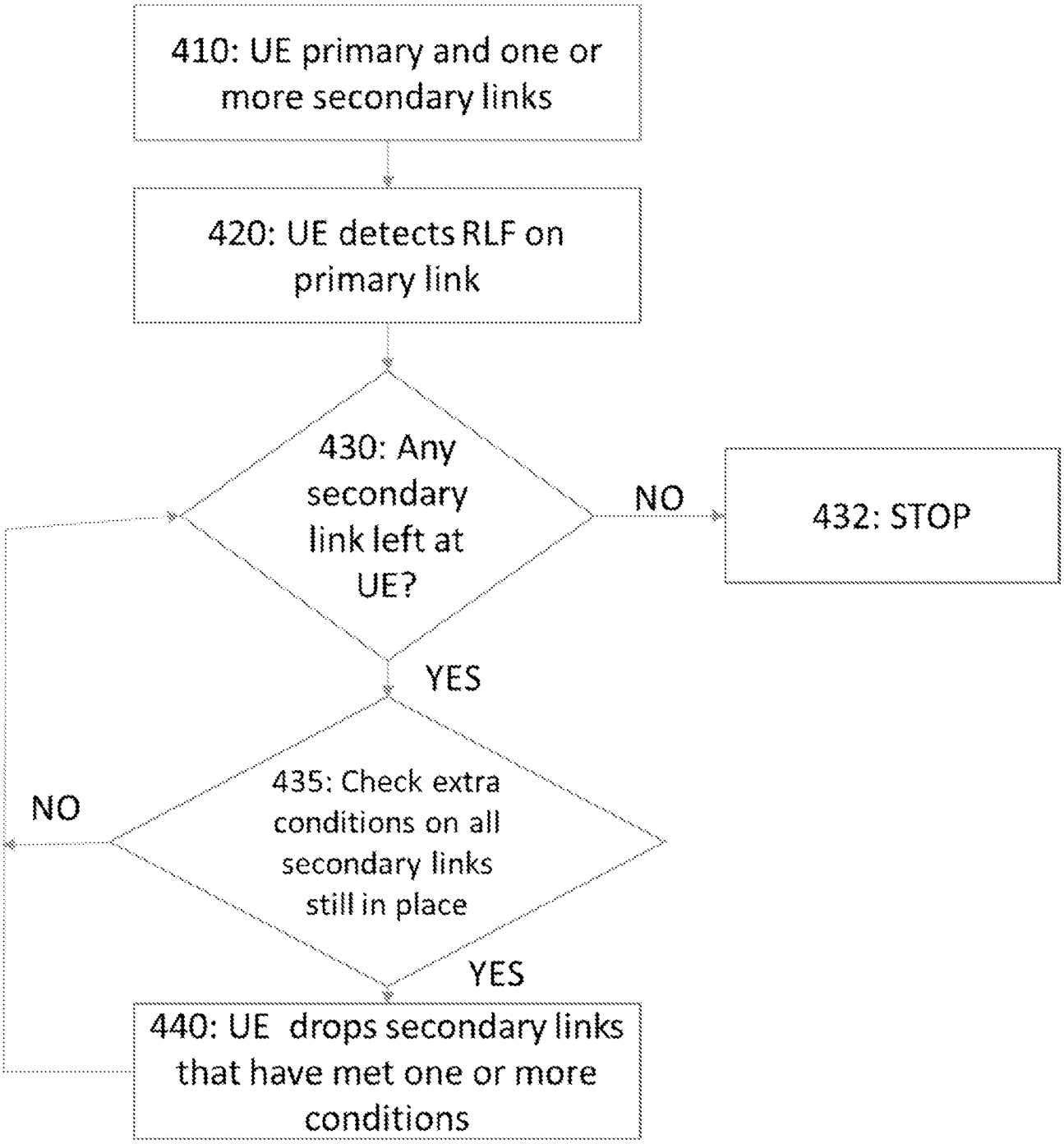
410: UE primary and one or more secondary links
420: UE detects RLF on primary link
430: Any secondary link left at UE?
NO
432: STOP
YES
435: Check extra conditions on all secondary links still in place
NO
YES
440: UE drops secondary links that have met one or more conditions

FIGURE 4

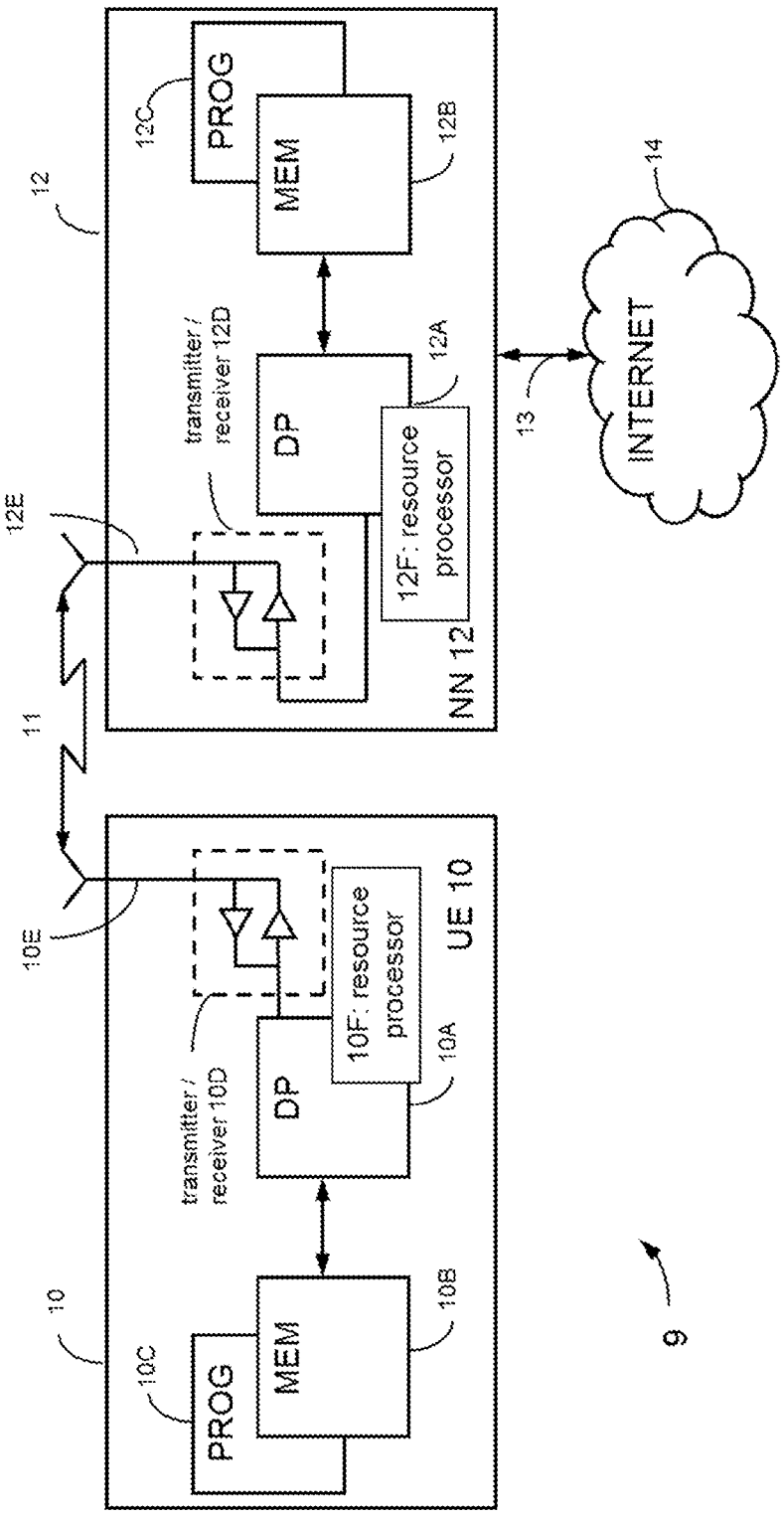
9
10
UE 10
10A
10B
10C
10D
10E
10F: resource processor
DP
MEM
PROG
transmitter / receiver 10D
11
12
NN 12
12A
12B
12C
12D
12E
12F: resource processor
13
14
INTERNET

FIGURE 5

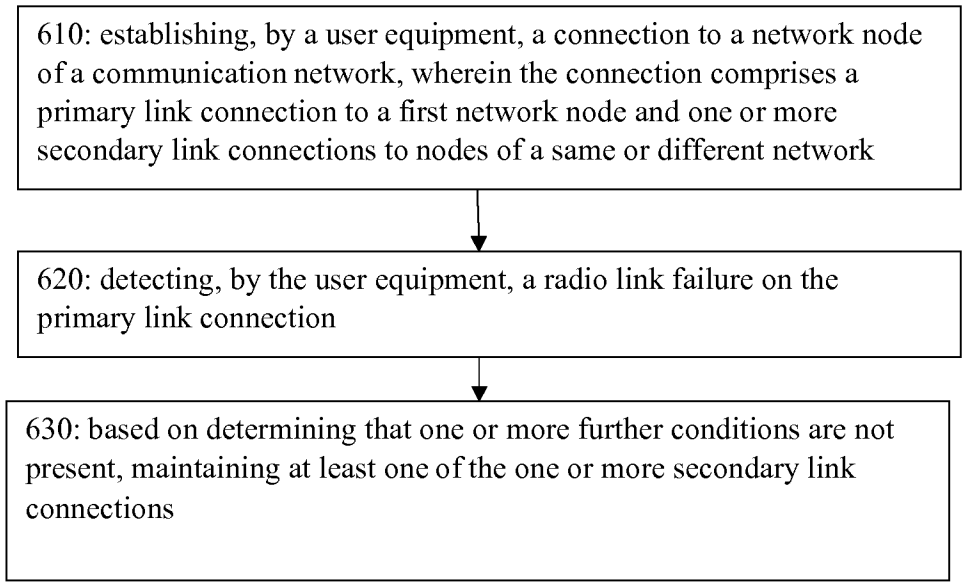
610: establishing, by a user equipment, a connection to a network node of a communication network, wherein the connection comprises a primary link connection to a first network node and one or more secondary link connections to nodes of a same or different network
620: detecting, by the user equipment, a radio link failure on the primary link connection
630: based on determining that one or more further conditions are not present, maintaining at least one of the one or more secondary link connections

FIGURE 6a

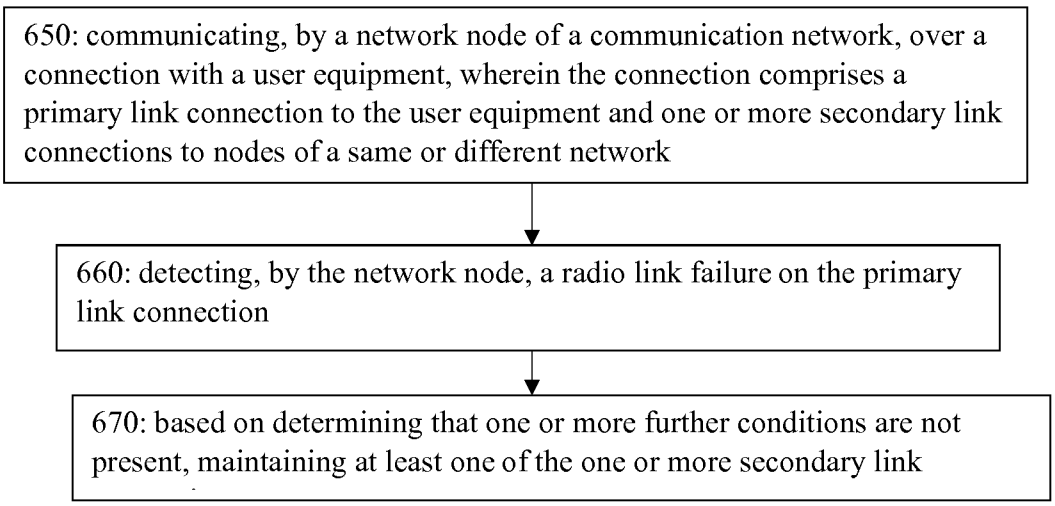
650: communicating, by a network node of a communication network, over a connection with a user equipment, wherein the connection comprises a primary link connection to the user equipment and one or more secondary link connections to nodes of a same or different network
660: detecting, by the network node, a radio link failure on the primary link connection
670: based on determining that one or more further conditions are not present, maintaining at least one of the one or more secondary link

FIGURE 6b

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI2017/050032

A. **CLASSIFICATION OF SUBJECT MATTER**

See extra sheet

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: H04W, H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

FI, SE, NO, DK

Electronic data base consulted during the international search (name of data base, and, where practicable, search terms used)

EPODOC, EPO-Internal full-text databases, Full-text translation databases from Asian languages, WPIAP, PRH-Internal, XP3GPP, XPAIP, XPESP, XPETSI, XPI3E, XPIEE, XPIETF, XPIOP, XPIPCOM, XPJPEG, XPMISC, XPOAC, XPRD, COMPDX, EMBASE, INSPEC, MEDLINE, PUBCOMP, PUBSUBS, TDB, NPL

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2016338137 A1 (MISHRA ANJALI [US] et al.) 17 November 2016 (17.11.2016) abstract; paragraphs [0003], [0019], [0020], [0022], [0035]-[0038], [0059], [0063], [0073], [0111]; claims 1, 8, 12, 17; fig. 6	1-13
X	US 2016366720 A1 (WU CHIH-HSIANG [TW]) 15 December 2016 (15.12.2016) abstract; paragraphs [0005], [0022], [0023], [0032], [0035], [0061], [0062], [0087], [0094]; figs. 2-5	1, 5, 6, 10, 14-30
A	US 2015049707 A1 (VAJAPEYAM MADHAVAN SRINIVASAN [US] et al.) 19 February 2015 (19.02.2015) entire document, especially abstract	1-30

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:	
"A" document defining the general state of the art which is not considered to be of particular relevance	
"E" earlier application or patent but published on or after the international filing date	
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention	
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone	
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art	
"&" document member of the same patent family	

Date of the actual completion of the international search	Date of mailing of the international search report
23 May 2017 (23.05.2017)	24 May 2017 (24.05.2017)

Name and mailing address of the ISA/FI
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI2017/050032

CLASSIFICATION OF SUBJECT MATTER

IPC
H04W 76/04 (2009.01)
H04W 76/06 (2009.01)
H04W 76/02 (2009.01)
H04W 36/14 (2009.01)
H04W 36/30 (2009.01)
H04L 29/06 (2006.01)
H04W 88/06 (2009.01)
H04W 88/10 (2009.01)

INTERNATIONAL SEARCH REPORT
Information on Patent Family Members

International application No.
PCT/FI2017/050032

Patent document cited in search report	Publication date	Patent family members(s)	Publication date
US 2016338137 A1	17/11/2016	WO 2016182670 A1	17/11/2016
US 2016366720 A1	15/12/2016	CN 106255101 A	21/12/2016
		EP 3104640 A1	14/12/2016
		TW 201644311 A	16/12/2016
		US 2017028090 A1	02/02/2017
US 2015049707 A1	19/02/2015	US 9414430 B2	09/08/2016
		CN 105474738 A	06/04/2016
		EP 3033918 A2	22/06/2016
		JP 2016530811 A	29/09/2016
		KR 20160042915 A	20/04/2016
		WO 2015023449 A2	19/02/2015